TROPICAL AGRICULTURE

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THE UNITED NATIONS FOOD CONFERENCE

FORTY-FOUR nations were represented at the United Nations Conference on Food and Agriculture which recently met at Hot Springs, Virginia, to consider the world problem of food distribution after the war. According to *Nature** "the recommendations show that most of the time and expert knowledge of the delegates to the Conference are devoted to the problem of providing more and better food for 2,000 million people to eat. Almost all their proposals for the expansion of production, the improvement of nutrition and the increase of consumption are specifically directed to this end. The prior charge on each country will be to provide the foods of high nutritional value such as milk, other dairy produce, vegetables and fruit, which are mostly perishable and best produced as near as possible to the centres of production. The want and need of these protective foods is almost unlimited. Beyond this basic domestic priority, consumption needs must be met from the most efficient sources of production wherever they may be found, with specific safeguards for the conservation of soil and its fertility.

Essentially this programme is a manifesto for freer trade and the international division of labour. Equally it is a programme of full employment—the development of industries and of purchasing power in backward areas as well as the maximum output of the right foodstuffs in the right places. It is not a policy of *laisser-faire* or of cut-throat competition, and although guarantees of stable prices to efficient producers to prevent the collapses which have been a bane in the past are essential to success, the protection of producers and restriction of supply by high tariffs or quantitative restrictions on imports must be firmly excluded. The protection of consumers and the maintenance of demand by social security measures or subsidies to special classes must be the weapons of policy.

The principal decision of the Conference is the creation of a permanent international organisation on the lines of the International Labour Organisation, to secure collaboration on measures to increase production, distribution, and consumption of food. Until the permanent organization can be established, an interim commission is to function

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in Washington. This Commission will be responsible for the promotion and co-ordination of research, and for the collection and dissemination of information. It will submit to the individual Governments recommendations for action along the lines agreed by the Conference, and will examine such questions as the development of agricultural resources, commodity arrangements, consumer co-operatives, land tenure and other subjects considered at the Conference.

Besides this section concerned with the permanent machinery to implement its recommendations, the Conference was organized in three other sections, each divided into a number of committees responsible for examining particular aspects of the general problem.

The report of the first section, on consumption levels and requirements stresses the relation between malnutrition and poverty and gives a picture of "world-wide under-consumption, malnurition and its attendant evils". Three-quarters of the 1,150 million inhabitants of Asia are living below decent health standards; malnutrition exists among the lower income groups of the United States and Europe; there are widespread deficiencies in tropical Africa, the West Indies and other colonial territories, and the War has aggravated a situation already serious. Without formulating a uniform set of dietary standards for general application, certain broad principles are laid down, and such standards as those evolved by The League of Nations Technical Commission on Nutrition are universally applicable. Advances in nutritional science permit the establishment of minimum dietary requirements in terms of calorie, protein, mineral and vitamin content. Government promotion of systematic education in food values, special provision for pregnant women, nursing mothers, infants and adolescents and the development of community services, school meals and factory canteens are recommended.

The second section, which examined the expansion of production and adaptation to consumption needs, distinguishes between the short-term and the long-term objectives. First, it recommends an immediate increase wherever possible in the acreage of crops for direct human consumption even at the expense of postponing the replenishment of livestock herds. While the shortages continue, the governments, individually and collectively, should endeavour to co-ordinate national production policies and the means of transport and distribution, and should take measures to prevent speculation and price fluctuations. Countries which, owing to their freedom from the impact of war, have been producing more than their normal output should maintain or expand their production and develop the manufacture of farm machinery and fertilizers.

The period of transition will involve considerable adjustments in policies. The long-term policy of each nation should be to increase the efficiency of production through better farming methods, measures for soil conservation, the encouragement of research, and the exploitation of undeveloped areas through land clearance, drainage and irrigation projects; and to introduce changes designed to foster the production at home of protective and relatively perishable food-stuffs. Nations should not attempt artificially to produce nutritionally desirable foods which can easily be obtained elsewhere. Besides measures designed to improve agricultural efficiency and promote research, this section of the Conference recommends that, to facilitate occupational adjustments, countries with large populations in relation to their agriculture should develop suitable industries for processing and preserving their own produce, and should be assisted to export processed articles rather than raw materials, and to import machinery and tools.

The recommendations of the third section, on the facilitation and improvement of distribution, are less definite, depending as they do on international agreement in the wider field of reconstruction. The Conference recognizes that the key to the long-term problem lies in full employment with generally increased purchasing power and improved standards of living. The need for maintaining a balance between agriculture and industry is recognized, and international trade barriers and restrictions are denounced. In the immediate post-war period it will be necessary to ensure the most economic distribution of available supplies and to avoid price fluctuations and unrestrained competition. Under-nutrition will necessitate international action on a large scale, and international commodity arrangements will be necessary: these should allow effective representation of consumers, the maintenance of adequate reserves and the orderly disposal of surpluses. Other recommendations are international standardization in methods of processing, preserving, storing, packing and transport; measures for protecting the consumer from unfair trade practices; and full use of such war-time developments as dehydration.

So much for the general programme, the technical soundness of which can scarcely be questioned. The translation of recommendations into action, however, involves the overcoming of long-standing political obstacles, national and sectional. While, for example, the maintenance of health in Britain during the War shows what can be achieved through a scientific nutrition policy and the planned distribution of basic foodstuffs, in Britain no less than elsewhere agriculture is unbalanced and distorted, and with vested interests created in uneconomic farming. The farming forced on nations by war-time scarcities and the severance of communications is poles apart from the programme of abundance that co-operation and common sense could devise in a peaceful world, and is dangerously close to the narrow nationalistic aspirations of politicians and producers.

That is the first issue upon which the Governments of the world must fasten. To translate into specific terms this vision of an efficient and fruitful world agriculture, based on the expansion of world production according to a functional division of tasks, will demand not only all the help that the proposed permanent international organization can give it, but also the understanding support of public opinion throughout the world."

A PROMISING NEW SOIL AMENDMENT AND DISINFECTANT *

The serious crop losses suffered by growers as a result of injuries to plants by specific organisms in the soil indicate the need for a low-cost disinfectant which could be applied as an insurance measure in soils suspected of harbouring such organisms. This need is particularly great where prediction of damage cannot be made prior to planting or in areas where the incidence of such damage is spotty or where the economics of the crop preclude the use of expensive materials.

Preliminary results obtained by the use of a mixture of 1-3 dichloropropylene and 1-2 dichloropropane indicate that this material promises to fill this need. The material used in these experiments was obtained from the Shell Development Company at Emeryville, California, from whom it is available in two grades, one an approximately 50-50 mixture of the two compounds and the other a crude form containing about 75 per cent. of the mixture, the balance being impurities of various kinds. It is low-priced compared with any competing product and, compared with chloropicrin, is extremely simple to handle. It is shipped in ordinary 55-gallon drums and can be handled without the use of a gas mask in the open air. In common with similar compounds, breathing of the fumes should be avoided and the precaution taken of promptly washing off with water any of the mixture which might be spilled on the hands or skin. No other commercial use for the material has thus far been found and no priorities are currently involved in its manufacture.

Tests with rapidly maturing vegetable crops grown in soil heavily infested with the root-knot nematode, *Heterodera marioni*, have shown that a very real measure of control has been obtained not only in the plot which was covered with asphalt impregnated paper used as a mulch paper before treatment, but also in a parallel plot which received no seal of any kind either prior to or after the treatment. This is particularly important when the needs of the small grower are considered. In these tests, injections were made at intervals 1 foot apart, the amount per acre being approximately 200 pounds. Furthermore, in these tests, the crude form of the mixture was used. This crude form contains some impurities, but its manufacture involves fewer processes and it is therefore cheaper.

Experiments in pineapple fields have been conducted since the spring of 1940. In these experiments, a dosage of 150 pounds of the mixture in pure form per acre was used and injections were made through the mulch paper. The results thus far have shown that in all the locations in which the treatments were applied, definite and favourable response in growth has been obtained. The results are particularly striking in an area where a complex, including at least Anomala beetle larvae (*A. orientalis*), nematodes and pythiaceous fungi, has resulted in serious plant failure. In all cases, the results can be compared with those from equivalent applications of chloropicrin and, without exception, the new treatment is at least equal to that material in its benefits.

Results in pineapple fields did not make themselves evident for over a year after treatment indicating that the soil disinfection, apart from its immediate effect in reducing populations of harmful organisms, had also affected the soil complex in such a way as to permit the plant gradually to show increasing improvement over the untreated checks. This was in direct contrast to the results with chloropicrin which, as usual, manifested themselves earlier with a dark-green growth typical of pineapple plants grown in chloropicrin-treated soil.

It is probably true that the broad function of treatments such as these is to amend the biological complex of the soil so that the end result expressed in terms of plant health and plant yield is favourable. Biological complexes in the soil may be radically changed through the elimination of some specific organism and the suppression or stimulation of others. Such changes may be as significant for the end result as the initial effect on the specific organism, particularly if the crop in question is slow in maturing.

Much experimental work remains to be done on the effect of the treatment of specific organisms, the range of practical dosages for varying soils and weather conditions and the possibilities of treating soil around growing plants. When the pineapple plant is used as the test plant in such experiments the final results are slow to accrue, but since the material (called D-D mixture for short) has such great potential usefulness for other more rapidly maturing crops in a great many agricultural areas, it seems advisable to present the preliminary results at this time so that these potentialities can be fully explored.—(*Science*, Vol. 97, No 2521, 1943.)

*Published with approval of Acting Director as Technical Paper No. 145 of the Pineapple Research Institute, University of Hawaii.

WITCHES' BROOM DISEASE INVESTIGATIONS

VI. The Infection of Flower Cushions and Pods of Cacao by *Marasmius Perniciosus* Stahel

BY

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1. Introduction

Marasmius perniciosus Stahel, the fungus responsible for witches' broom disease of cacao, attacks any young actively growing tissues, including flowers, flower cushions and young cherelles, all of which can be infected, just as can the vegetative buds, with the consequent formation of a variety of malformed growths or witches' brooms. Artificial infection of flower cushions and of cherelles has previously been demonstrated only by Stahel (8) in Suriname, and it was thought desirable to repeat and if possible amplify his results under Trinidad conditions. The results of a series of successful inoculation experiments are given here, together with a general description of natural infection of flower cushions and young cherelles in the field.

The severe loss caused by pod infection is obvious on even cursory examination of the crop in any severely infested area, where, at certain seasons, the majority of the pods on the trees show symptoms of infection. Records of the proportion of witches' broom diseased pods on two estates are summarised in Table I, through the courtesy of the Department of Agriculture. At River Estate, certain fields, from which in 1940 10-15 per cent. of the pods harvested were infected, in 1942 produced a crop of which 75 per cent. was infected, this latter figure being typical of severely infected areas. In general, the beans in an infected pod are worthless, although, in pods attacked at a late stage, some of the beans may be undamaged.

The total losses due to the disease cannot be estimated but must be greater than the figures quoted above, which give only the percentage of diseased pods among those harvested. In addition to the indirect effects of severe destruction of vegetative shoots, the yield is reduced by the failure of infected pods to reach maturity, although further study is required before this latter factor can be disentangled from cherelle wilt. The effects of cushion infection and destruction are difficult to estimate, but are probably less important, in spite of the fact that, on some trees, a very large number of the cushions are infected and bear no healthy flowers.

The incidence of infection depends on the weather, being much higher in the wet than in the dry season; but because there is generally an interval of 3 to 4 months between an infection and the final destruction of the pod, a high proportion of the pods harvested at the beginning of the dry season will be diseased, and a similar high proportion of the pods harvested at the beginning of the wet season will be healthy.

It has been shown by Baker and Crowdy (1) that susceptibility to pod and to cushion infection varies from tree to tree, there being no correlation either between the numbers of infected pods and cushions or between the numbers of infected pods and vegetative shoots. Certain trees which set and mature the majority of their pods in the dry season, when conditions are unfavourable for infection, show an apparent resistance to the disease which might not be maintained under more humid conditions.

TABLE I

Year	W.B.D. pods	Total pods	% W.B.D. pods
River Estate (Field 8)			
1935/36 ...	—	6682	0.00
1936/37 ...	9	6148	0.15
1937/38 ...	440	8455	5.20
1938/39 ...	629	3699	17.00
1939/40 ...	1155	5648	20.45
1940/41 ...	505	3509	14.39
1941/42* ...	1196	3026	39.52
1942/43* ...	1087	5313	20.46
Marper Estate (Whole Estate)			
1930	120	477252	0.03
1931	191	418951	0.05
1932	564	424692	0.13
1933	4365	408258	1.07
1934	5390	366200	1.47
1935	7604	435437	1.75
1936	16530	417240	3.96
1937	38010	438408	8.67
1938	21452	611497	3.51
1939	23187	230891	10.04
1940	48603	408934	11.89
1941	15582	381794	4.08
1942	12383	188191	6.58

*Random sample of 500 trees distributed over the whole estate.

Cushion and pod infections were first described by van Hall and Drost (5). Since then, Nowell (7), van Hall (4) and Briton-Jones (3) have all published accounts, and Trueblood (10) has recently produced a detailed survey, with many illustrations, some of which are reproduced here.

On cushions, infection results in symptoms which range from a single infected flower (Fig. 6 (*a*) & (*b*)) to the formation of large vegetative shoots (Fig. 8). Infected flowers are abnormally large and have thicker pedicels which, owing to their greater rigidity, stand straight out from the cushion

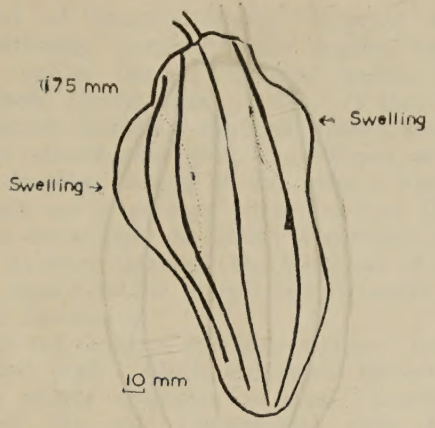

FIG. 1 (*a*). Swollen pod

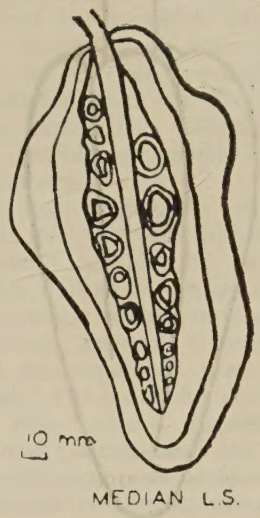

FIG. 1 (*b*) Longitudinal section of swollen pod

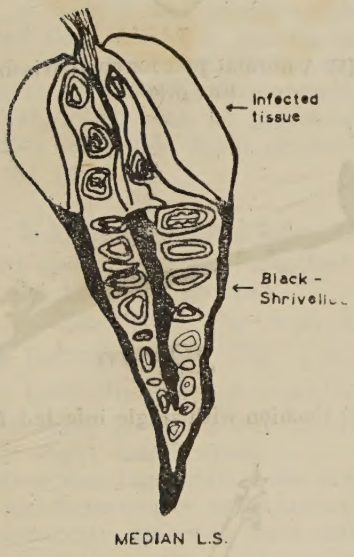

FIG. 2 Longitudinal section of a wilting swollen pod

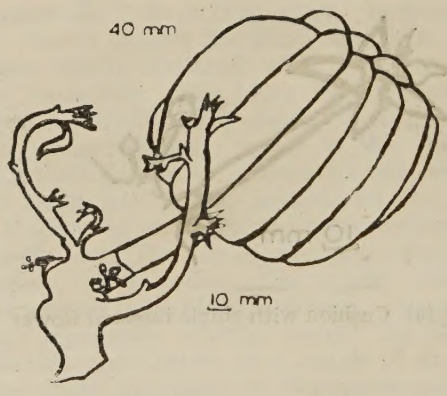

FIG. 3 Indirectly infected pod

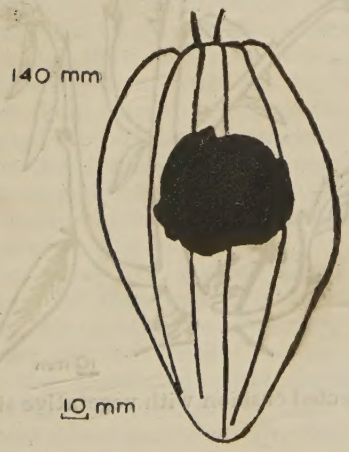

FIG. 4 (*a*) Indurated pod

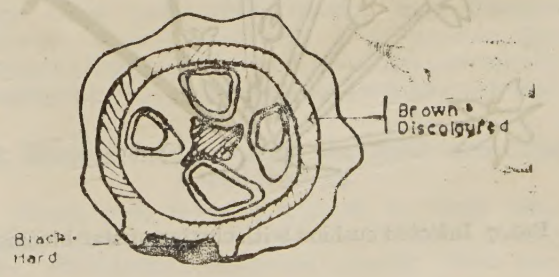

FIG. 4 (*b*) Cross section of indurated pod

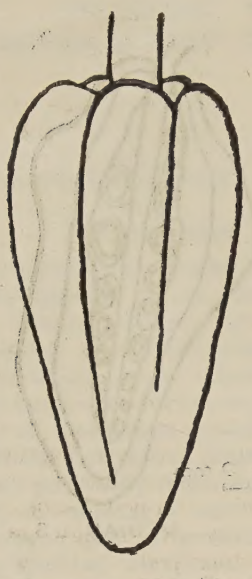

FIG. 5 (*a*) A systemically infected pod

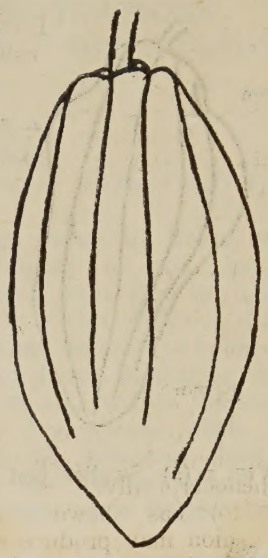

FIG. 5 (*b*) A normal pod for comparison with FIG 5 (*a*)

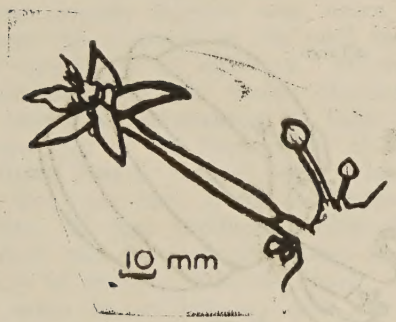

FIG. 6 (*a*) Cushion with single infected flower

FIG. 6 (*b*) Cushion with single infected flower

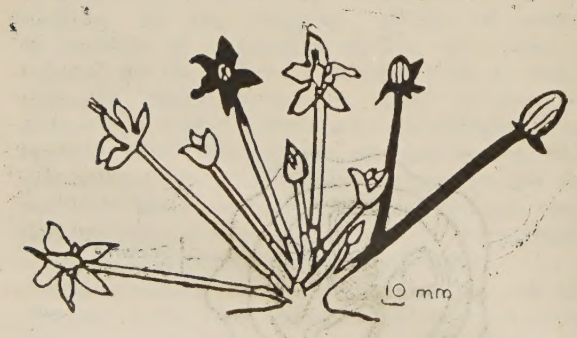

FIG. 7 Infected cushion with cluster of star-blooms

FIG. 8 Infected cushion with vegetative shoots

instead of hanging limply. Infected flowers, on withering, persist on the cushion for some time, unlike normal flowers, which, if not fertilised, abscise after 3 days. If the cushion is infected, clusters of abnormal flowers, sometimes called 'star-blooms' (Fig. 7) are found, or shoots may develop, ranging in size from a fraction of an inch up to perhaps 18 inches long (Fig. 8). These shoots may be wholly vegetative or may have axilliary flowers. The latter are of interest with regard to the morphological nature of the flower cushion (9).

Infected cushions may also produce "indirectly infected pods", which are much distorted and often nearly spherical or even "strawberry" shaped (Fig. 3). Unpublished work done in Trinidad by Posnette has shown that such pods develop parthenocarpically.

Trueblood (10) has shown that, following infection, a cushion may produce either healthy or diseased flowers or may entirely cease flower formation. By trimming off the exposed parts of an infected cushion the development of further infected out-growths can be prevented, some of the cushions so treated again producing healthy flowers and pods.

2. Symptoms of Pod Infections

Infected pods have been classified by Stahel (8) into the following groups:

(1) Swollen pods (Fig. 1 (*a*) & (*b*))

(2) Indurated pods (Fig. 4 (*a*) & (*b*))

(3) Indirectly infected pods (Fig. 3)

This grouping is convenient and is followed here with slight modifications.

A swollen pod (Fig. 1 (*a*)) is one in which there is a marked hypertrophy or departure from the natural symmetry, and such pods may have one or several infections with corresponding swellings. On sectioning and staining, using the cotton blue-lactophenol technique, the fungus mycelium can easily be detected, ramifying between the cells and in the mucilage canals of the infected area. This mycelium is characteristic in appearance and in doubtful cases provides a sure method of detecting infection. Such swollen pods do not reach maturity, as necrosis sets in, usually when the pod is about three-quarters grown. Typically the infected area assumes a speckled appearance owing to the discolouration of small groups of cells both on and below the surface; discolouration rapidly becomes general in the infected area and finally involves the whole pod.

On the cacao tree a much larger number of cherelles is set than ever reaches maturity, the majority succumbing to "cherelle wilt". If an infected cherelle "wilts" before necrosis has started, the uninfected parts degenerate more rapidly than the infected, so that the infected area retains its natural colour after the surrounding tissues have become yellow or even blackened (Fig. 2). In cross-section the infected part remains white after the uninfected tissues have turned brown. Trueblood (10) has also noted that if infected but unwilted cherelles are cut across, the browning of the internal tissues, which occurs on exposure, proceeds more rapidly in the uninfected than in the infected area. Attempts to hasten the detection of infection by 'wilting' inoculated cherelles artificially were, however, unsuccessful.

Indurated pods (Fig. 4 (*a*)) are those in which there is infection but no hypertrophy. Such infections cannot be detected until the pod is nearly mature, when necrosis occurs in the infected area causing a brown or black patch on the surface. Internal necrosis is more widespread than would be expected from the external discolouration. The beans are usually all infected and, when ripe, adhere together instead of separating, though sometimes a few are unaffected. Diseased cherelles and pods become very hard and woody, especially on drying—hence the names indurated or stone pods. Pods with as many as 6 separate infections have been found, but single infections are more common.

To the above may be added a third type of infection, in which the whole pod is hypertrophied, although it remains symmetrical. Such pods have thickened pedicels and broad shoulders which taper straight to a blunt tip, giving a "carrot-like" shape (Fig. 5 (*a*)). In cross-section, the tissues outside the ovary are thick, and the beans usually contain a clear liquid in place of the cotyledons. This latter feature occurs in all types of infected pods but is most consistently and characteristically found in this third type. Such pods do not reach maturity, for, when they are about half grown, necrosis sets in, starting as a speckling of the ground tissues, which spreads rapidly until the whole pod is a characteristic uniform brown colour. The rapidity with which this necrosis takes place is striking. A pod, which was apparently healthy except for distortion, will turn quite brown in a couple of days. The pure white mycelium of *Marasmius perniciosus* can often be seen in the cavities round the ovules of such pods. Experimental evidence suggests that these pods are systemically infected, presumably as very young cherelles, and "systemically infected pods" is suggested as a name, for want of anything more apt (Fig. 5 (*a*)).

Indirectly infected pods, Stahel's third class are those pods which develop from diseased flowers, already described. It is possible that infected flowers, if fertilised, may form systemically infected pods, but this has not been demonstrated.

3. Witches' Broom Disease Compared with Other Pod Diseases

Cacao pods may be infected by fungi other than *Marasmius perniciosus*, in Trinidad notably by *Phytophthora palmivora* causing black pod, by *Botryodiplodia theobromae* causing brown pod and by *Colletotrichum* spp. causing anthracnose. These different pod rots can usually be distinguished with some degree of certainty in the

field, but it must be emphasised that experience is necessary, and that doubtful examples are found, which can be identified only by isolation of the fungus concerned. A few points are noted here which have been found useful in the field for distinguishing these diseases from each other and more especially from witches' broom disease. Fuller descriptions are given by Nowell (7) and Briton-Jones (3). (It is rarely possible to decide by what agent old and blackened pods, in which the original pathogen has been followed by various saprophytic fungi, were destroyed).

Phytophthora palmivora causes a sharply demarcated brown lesion which later turns black. Infection usually starts either at the tip or at the shoulders, and spreads rapidly throughout the pod. In cases where two neighbouring pods are touching, infection may start at the point of contact between them. Unlike witches' broom diseased pods, the internal is usually less than the external necrosis. The damage to the beans, which remain loose, and the discolouration of the bean cavity, are not so marked as in witches' broom disease. In wet weather, a white bloom consisting of the mycelium and sporangia of the fungus can be seen on the surface. The pod does not become hardened nor is there any swelling or distortion.

Botryodiplodia theobromae is a weak parasite which can attack only damaged cacao pods, commonly gaining entry in Trinidad through wounds made by the little red headed wood-pecker (*Veniliornis kirkii kirkii*). The pod blackens rapidly and the dark mycelium of the fungus can be seen in the bean cavity. Such pods have usually a "fermenting" smell, presumably owing to the entry of yeasts through the wound. *Botryodiplodia theobromae* is found also as a saprophyte on cacao shells and on over-ripe pods, the pycnidia developing in large numbers on the surface.

Colletotrichum species cause numerous sunken lesions which are known as anthracnose. The fungus is often confined to the shell, but if it penetrates to the beans, especially if these are young, considerable damage is done. The lesions are found on any part of the pod and, when old, show characteristic acervuli consisting of pinkish masses of spores. The shell of pods attacked in this way is often very soft and light brown in colour.

Thus, pods infected by *Marasmius perniciosus* may be distinguished by one or more of the following symptoms:—

(1) Swelling or distortion of the pod as already described.

(2) Marked internal as compared with external necrosis, and severe damage to mucilage and beans, which adhere together.

(3) The presence of pure white cottony mycelium.

(4) The hardening of the shell of the pod.

It should be noted that a speckling of the ground tissues is not necessarily characteristic of witches' broom disease, being sometimes associated with other diseases, such as black-pod.

If laboratory facilities are available, field diagnoses may be confirmed by isolation of the fungus, or by microscopic detection of its mycelium, but these methods are too laborious for general surveys.

4. Inoculation Experiments

The only reference to the artificial infection of pods with *Marasmius perniciosus* is that of Stahel (8). In a preliminary experiment, spores were allowed to fall from mushrooms on to 380 flowers and ovaries; only 7 pods reached maturity, but of these 2 were diseased. In a later experiment, 185 pods were inoculated, and 64 reached maturity; of these, 39 were diseased.

Stahel concluded that swollen pods resulted from the infection of cherelles less than 20 mm. long; that no infection, or infection of the shell only occurred if the pod was over half grown at the time of infection; and that indurated pods developed when cherelles were infected between these two stages. In the same paper, Stahel reported the inoculation of 19 flower cushions, of which 5 became diseased. Trueblood (10) inoculated 140 cushions with 4 successes.

Stahel showed that the germ tubes penetrate through the stomata (which are absent on unfertilised ovaries); that the sporophore deposits its spores mainly between 6 p.m. and midnight, depositions being connected with temperature changes; and the spores germinate rapidly in water and are short lived, especially under drying conditions. Baker and Crowdy (2) have confirmed and extended these findings on the deposition and biology of spores.

Inoculations were usually made at night during the wet season when the atmosphere is often saturated. Freshly cut sporophores were placed on slides in Petri dishes, kept humid with a pad of moist cotton wool. If placed in some cool spot, an adequate spore deposit was usually obtained by 9 or 10 p.m. By artificial cooling sporophores could be induced to deposit spores at other times of the day, but the germination of such spores was poor and this method was not employed. The spores were removed with a paint brush, suspended in water and sprayed with an atomiser on to the cherelles to be inoculated. Spore germination was tested by spraying some of the spore suspension on to a slide and counting the number which subsequently germinated in a sample of 100 spores.

To obtain good germination, young, fresh sporophores should be used and inoculations made as soon as possible after spore deposition. The highest percentage germination recorded was 54 per cent. but 30 per cent. was more usual, and was considered quite adequate. If old sporophores are used, a deposit may be obtained, but large numbers of bacteria, which appear to interfere with germination are also present.

Seedling trees of the Trinitario type, with strong Criollo affinities, conveniently situated in the College grounds, were used for most of these experiments, but trees of an Amazonian Forastero type from Brazil were also used on one occasion.

There is very little natural witches' broom infection at the College and it was not considered necessary to mark uninoculated cushions and pods as controls. During these experiments only about a dozen vegetative brooms were removed from the trees, representing a very low degree of natural infection. The pods which were inconvenient for artificial infection were at intervals carefully examined for natural infection, but none was discovered. On some trees mass inoculations were made on localised areas of the trunk and main branches and infection developed only in these areas.

In the course of these experiments 262 cushions were inoculated of which 60 developed infection. 23 per cent. success cannot be considered high, but on some occasions either the spore suspension was unsatisfactory or the weather conditions unsuitable; moreover, some of the inoculated cushions have remained dormant. Cushions in all conditions, from those bearing minute flower buds to those with grown flowers, were infected. Symptoms usually became visible 3-5 weeks after inoculation, although in some cases longer intervals elapsed. The various types of infected cushion which are found in the field were all artificially reproduced. Of the 60 infected cushions, 26 developed both infected vegetative shoots and abnormal flowers, two produced shoots only, and 32 formed only infected flowers. Cushions producing vegetative shoots behave in one of two ways; either the vegetative broom appears shortly after inoculation, usually accompanied by infected flowers, or the vegetative broom develops as long as 3 months after inoculation, the original infected flowers having dried up and fallen off. This behaviour suggests that the tissues of the cushion may either be infected at once or that the infection may spread back slowly into the cushion from the infected flowers. In this latter event a delayed development of symptoms occurs at the succeeding "flower flush" (It has been shown by McKee (6) that cacao produces its flowers in flushes which correspond to the leaf flushes).

On artificially infected cushions, two "indirectly infected" pods were formed, which grew until a few centimetres long and then rapidly turned brown; neither had developing ovules.

The period during which cushions remain alive after infection varies greatly. A single infected flower will sometimes dry in a few days, but a typical star bloom persists for a month or two. If vegetative shoots are formed they remain green for one or two months and then dry out.

A cushion has a large number of buds and, as mentioned above, if the tissues of the cushion become infected, green brooms may develop several months after the original infection took place, green and dry brooms being sometimes found on the same cushion. For this reason a cushion infection persists in an "active" condition for much longer than a vegetative infection, although indirect evidence suggests that either the fungus eventually destroys the cushion or itself dies out, the cushion again producing healthy flowers.

5. Results of Cherelle Inoculation

594 cherelles were inoculated and of these 102, or 17 per cent. became diseased. This low figure is due partly to factors mentioned under cushion inoculations, but also to normal physiological wilting of inoculated cherelles occurring before sufficient time had elapsed for symptoms to develop. In one experiment 62 per cent. of the inoculated cherelles were infected.

The length of each cherelle was noted at the time of inoculation, and Table II shows the percentage of successes for the various lengths. Of the original 594 inoculated cherelles, 290 wilted within three weeks and were disregarded in these calculations. The table is divided into two parts, the first giving the combined results of 13 separate experiments on the Trinitario cacao, the second the results of a single experiment on Brazilian Forastero cacao.

TABLE II

POD INOCULATION AT I.C.T.A.

Cherelle length in cms.	Number inoculated	Number successful	% success
Field 1			
0-0.9	57	12	21
1-1.9	86	28	33
2-2.9	60	17	28
3-3.9	17	4	24
4-4.9	14	5	36
5-5.9	4	2	(50)
6-6.9	1	0	(0)
7 and over ...	8	0	0
Field 2			
0-0.9	—	—	—
1-1.9	4	2	(50)
2-2.9	9	5	56
3-3.9	18	16	89
4-4.9	9	7	78
5-5.9	3	3	(100)
6-6.9	2	1	(50)
7 and over ...	12	0	0
Totals ...	304	102	33

Cherelles up to 6.0 cms. in length can be infected, and the results suggest that all cherelles below this limit are equally susceptible.

The period elapsing between inoculation and the first appearance of symptoms may be as short as 3 weeks, or as long as 4 months. The successful inoculation of small cherelles less than

3 cms. in length usually results in visible symptoms after 4-6 weeks. Cherelles which are inoculated when larger than that rarely show distortion, and symptoms appear only when the pod has begun to ripen several months later. Small cherelles are, however, sometimes infected without any resultant distortion. A number of "systemically infected" pods developed from small infected cherelles, mainly about 1 cm. long at the time of inoculation. In these, necrosis often did not take place until as long as 3 months after infection.

The damage sustained by the pod depends on its size at the time of infection. Thus a small infected cherelle does not usually reach maturity, while cherelles infected when 4 cms. or more in length may ripen with some beans unharmed, though even in the latter case all the beans may be destroyed, especially if the pod is not picked promptly when it ripens. In no instance was infection confined to the shell. This point requires further investigation as it does not confirm the work of Stahel, who found that when older pods were infected, partial infections, confined sometimes to the shell alone, were produced. Field records in Trinidad also suggest that infections of this type may occur.

Infection of fan brooms has been shown by Baker and Crowdy (2) to be dependent on atmospheric humidity to the extent that successful inoculations are possible only in the wet season. A comparison of the humidity records for nights when successful and unsuccessful inoculations were made in the experiments described above, which were all conducted in the wet season, did not reveal any striking differences.

In a second series of experiments, some of the inoculated cherelles were covered with glass tubes supported by a ring of plasticine on the trunk of the tree, and containing pads of moist cotton wool. The tubes were removed the morning after inoculation, before the sun had risen sufficiently to cause excessive heating. Cherelles treated in this way were therefore surrounded by a saturated atmosphere for at least eight hours. The combined results of these experiments are given in Table III.

TABLE III

No tube Inoculated		With tube Inoculated		With tube Not Inoculated	
Healthy	Diseased	Healthy	Diseased	Healthy	Diseased
3	6	3	6	8	0
0	6	0	10	—	—
0	7	0	10	—	—

It will be seen that this method did not increase the proportion of successes, therefore, pending the development of a satisfactory technique all that can be done is to confine inoculation experiments to the wet season.

6. Summary

1. The work of Stahel in Suriname on the pod- and cushion-infecting stages of witches' broom disease has been confirmed and amplified under Trinidad conditions.

2. Climatic factors are of considerable importance, as infections only occur during the wet season, but there may be a lag of up to four months between infection and the appearance of visible symptoms on the pods. Cushions usually show symptoms three to five weeks after inoculation but may become dormant and produce neither diseased flowers nor shoots until the next flower flush.

3. All types of diseased cushion, including those with parthenocarpic pods, were produced by artifical inoculation.

4. Diseased pods were classified as swollen pods, indurated pods and indirectly infected pods, following the system devised by Stahel. Swollen and indurated pods were readily produced by artificial inoculation; but the development of the indirectly infected or 'parthenocarpic' pods has not been satisfactorily elucidated.

5. Cherelles infected when less than 3 cms. in length usually develop into swollen or distorted pods, while larger cherelles become indurated but not distorted. According to Stahel, pods can be infected when more than half-grown, but only develop lesions in the shell. The existence of this type of infection in Trinidad is suspected but has not so far been demonstrated by artificial inoculation.

6. Attempts to improve the inoculation technique, and thus to make results more certain during the wet season, and perhaps, possible even in the dry season, have so far proved unsuccessful.

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NOTES ON THE CRYPTOSTEGIA PLANT

(The following notes on "Cryptostegia grandiflora" which is now being cultivated on a large scale in Haiti and Mexico for the production of rubber have been culled from an article by R. Symontowne published in "India Rubber World", Vol. 108, Nos. 2 and 3 of 1943 under the title of "Cryptostegia Research in Haiti." In Haiti the planting of 100,000 acres of the crop has been entrusted by the government to the Société Haitiano-Americaine de Développement Agricole known as Shada, which recently established a 150-acre experiment station near Gonaives on the west shore of Haiti.—Ed.).

History and Cultivation of Cryptostegia

The plant, a native of countries bordering on the Indian Ocean, was introduced into Haiti in 1912 by a German pharmacist and botanist. It escaped from his garden near Gonaives and spread over a 500-acre area. SHADA uses these escape plants as a source of seed and experimental material.

Cryptostegia belongs to the milkweed (*Asclepiadaceae*) family, many of whose members yield latex, some of which contain rubber. There are two recognised species: *C. grandiflora*, of high rubber content, and *C. madagascariensis*, containing little rubber, but much resin-like material. Since the plant hybridizes freely it is probable that most individuals are intermediate between the two species.

Cryptostegia is extremely hardy, and grows with astonishing rapidity. Its growth is far faster than that of any other known rubber plant.

The plant's natural habitat is in arid regions, but there is ample evidence that it grows well under a wide range of climatic conditions. It does not re-seed easily in areas of high rainfall. In regions of pronounced wet and dry seasons, *Cryptostegia* may defoliate in the dry seasons. It does not lose its leaves where there is constant aridity. *Cryptostegia* produces a root system as long as its top growth and is thus able to stretch at least 10 feet underground for water. A water table of from six to ten feet is believed optimum. The plant apparently has no soil preference, growing well in salty, acid, or alkali soils of almost any texture.

The seeds show remarkable viability and from 85 per cent. to 90 per cent. germinate. Seeds have the capacity of lying dormant in dry soil and germinate when the rain comes after droughts lasting from six to eight months.

It is this high viability and resistance to drought which enables planting to be done by seed straight in the field; the nursery stock being held in reserve to fill up blanks. The seeds are covered with a half-inch of soil as it has been found that optimum coverage is from a quarter- to a half-inch. The exact depth of coverage is important. The seedlings seem to have difficulty in piercing more than a half-inch of earth; while there is danger of the wind uncovering them if they are planted too close to the surface. The present planting is in double rows a foot apart with the plants one foot from one another. The double rows are four feet apart. Two seeds are being allowed to each hole.

When supplied with plenty of water, the seedlings break through in three days and are an inch and a half high in a month; 4½ inches high in the next month; 12 to 14 inches after three months, and five feet in five months. Plants a year old are 12 to 14 feet tall. The longest unsupported stem yet found at Gonaives measured 16 feet eight inches. Adult stems are capable of growing four inches a day.

The plant has two kinds of stems: one bears flowers and sets fruit; the other has a tendril-like character. These latter are called "tipping whips", or "T-whips". If they are supported, growth is tremendously accelerated and may be as much as 14 feet a month. Such growth, however, is spindly and must be discouraged when the plant is used as a source of rubber.

Cryptostegia at Gonaives flowers in from five to seven months. The plant, however, seems to attain full growth maturity in 18 months. Its maximum life is not known, but individuals of great age have been found. The flower branches set from 20 to 50 blossoms, and from 10 per cent. to 50 per cent. of these set fruits, which ripen in about four months in the form of large double pods. Each pod contains from 300 to 350 seeds and it is estimated that there are 47,000 to 49,000 seeds in a pound of seed.

Young plants are attacked by aphids which thus far have been easily controlled by nicotine sulphate spray. There has been some appearance of scale in older plants, but careful search among the vines which are growing wild has failed to reveal other insect pests.

Cryptostegia appears exceptionally immune from disease, but there is always the high probability that under plantation conditions diseases will develop, particularly as a result of tapping traumatism.

From an agricultural standpoint *Cryptostegia* is an eminently satisfactory plant. SHADA is experiencing little difficulty in getting its huge acreage planted swiftly, and there is no reason to think the plant will not flourish in its plantations.

Latex Collection and Coagulation

An extremely simple, low cost coagulating and sheeting process has been developed at Gonaives. While this probably will be improved it now seems entirely adequate. The major problem with *Cryptostegia* is that of the collection of rubber in the field and it is on the solution of this problem that the whole success of *Cryptostegia* as a commercial rubber source depends.

The possibilities of mechanically and/or chemically extracting rubber from *C. grandiflora* have been explored but so far the results have been uniformly negative. No commercial process comparable to the pebble mill treatment of guayule,

for example, is possible. This would appear to leave only some method of tapping, as *Hevea brasiliensis* is tapped.

But, compared to the large bole of the *Hevea* tree, *C. grandiflora* presents only its tiny stems. (A T-whip at the tapping point may have a diameter of four millimetres.) Where in a 24-hour period *Hevea* delivers latex in ounces, a *Cryptostegia* stem bleeds its few drops of latex in a matter of minutes. Moreover, while Hevea is planted about 150 trees to the acre, *Cryptostegia* is being planted at the rate of 10,000 plants to the acre. Each *Hevea* tree offers a single tapping operation every other day. Each *Cryptostegia* vine has from one stem to three stems and must be tapped daily. This means that SHADA's 100,000 acres will contain from one to three billion stems that will have to be tapped every day.

In addition *Cryptostegia* develops waste rubber which must be collected. The cut surfaces of the *Cryptostegia* stems form small plugs of rubber which will have to be gathered and later separated from the plant material to which they adhere. Depending upon weather conditions, from one-fifth to one half the total rubber yield will be in this waste form.

It can now be seen that the tapping or "tipping" of *Cryptostegia* is the problem of cheaply cutting huge numbers of small stems daily, bleeding the latex into vessels, and carrying vessels and waste rubber plugs to the factory.

Pilot scale tipping which is done at Gonaives when sufficient plants mature may be described as follows: wooden posts are set at regular intervals between the plant rows; each post serves for eight or more plants. The T-whips are all found on the north side of the plant because *Cryptostegia* has compass properties. The tips are brought down and held in place in a rack or clamp at the top of the post. Here tips are conveniently exposed to the tipper's knife. Small vessels hung on the posts serve to catch the dripping latex, and these vessels may be collected at any convenient later time. Bleeding stops after about 12 minutes. The rubber plugs which form over the cut surfaces remain *in situ* and are gathered at the time of the following day's tipping. At present plugs and plant material are hand-separated to be crêped locally for shipment as scrap.

Thus it will be seen that here is a multi-step operation with each step conditioned by all the others. Among the questions the Gonaives station seeks to answer are: What kind of knives or other cutting tools should be used bearing in mind the vast numbers which will be required and war-time material scarcities? What sort of vessels? What sort of posts or other supports should be used between the rows in a country where termites and post beetles abound and where lumber is not too abundant? Also, what sort of rack or clamp device?

As vexing as any other element in the problem is the matter of clamp devices which may be used to hold the stems for tapping. They must be simple, cheap, and available in quantity. These must seize and hold the stem securely with a minimum of the tipper's attention. They must release the stem just as easily so that from day to day a stem may be advanced to present new cutting points. The present practice is to start tipping just above the second internode and to continue, removing about one inch of stem daily, until the heavy, woody portion of the T-whip is reached.

Cryptostegia's own growth habits will add further difficulties to tipping on a plantation scale. *C. grandiflora* seedlings look not unlike small fruit trees, but, when they have reached a height of some three feet, they quite suddenly exhibit the vigorous twining characteristic of the species. The water-shoots take a tendril character, and whatever they touch, they seize and entwine. The floral branches too will occasionally develop twining tendencies. Thus a full grown, untended plant growing in a field presents a matted mass of T-whips, some waving high in the air, endlessly searching for support, and others tightly wrapped about their neighbours. Adult plants at Gonaives, sharply pruned back in September, in November were a wilderness of tangled branches. It is quite apparent that *Cryptostegia* will have to be tipped constantly and probably, in addition, pruned, if the plantations are not to degenerate rapidly into impenetrable jungles.

The hardiness of *Cryptostegia* and its twining characteristics has raised the question of whether it is likely to become a plant menace to agriculture in Haiti should its cultivation be abandoned when *Hevea* rubber returns to the world market after the war. The present consensus is that it is unlikely to become a weed pest since, in nature, the plant does not spread rapidly; the conditions of optimum germination and seedling growth are rarely met. Moreover experiments show that the green plant burns readily so that fields could probably be destroyed by fire. It is also doubtful if the plant could survive extensive damage to its crown.

Difficult as the tipping problem is proving, it is confidently expected that a practical technique will eventually be established depending on many more factors than those outlined above. Atmospheric conditions, for example, are being found to exercise a profound influence on the amount of latex and probably upon its rubber content. Gonaives is frequently subjected to strong, dry winds from the north which greatly lower the latex volume, probably through their dessicating influence. More latex is known to be available when a rainy night is followed by a dry, bright day. Present data indicate that the greatest latex flow is during early morning hours, falling off during midday heat, and rising again at the approach of evening. Earlier observations on the plant indicated the contrary, that is, that the greatest yield was at midday.

Investigation of Plant Characteristics

Genetic researches on the plant revealed that the many hybrid forms intermediate between the two species present the possibility of combining the beneficial characteristics of the two species in clones. Plants having a large number of T-whips of large cross-sections are desirable since the T-whip is most suitable for tipping and since it has been established that latex flow is in part a function of cross-sectional area. T-whips of the same age vary from three millimetres to 6.5 millimetres in diameter, and the yield of rubber varies from three to 42 drops per T-whip at a single tipping. *C. grandiflora* has the highest rubber content and *C. madagascariensis*, the highest latex flow per unit of cross-sectional area. Besides *C. grandiflora* has a pronounced whip forming habit; while *C. madagascariensis* has the greater production of floral shoots. It is proposed to take advantage of these variations to establish clones of high yield. Here *Cryptostegia* has a marked advantage over other commercial rubber plants because its rapid growth will permit the early establishment of clones.

Almost 100 per cent. success is obtained with every form of budding and grafting; firm union between scion and stock is established in about three days, and the scion grows as much as an inch and a half in six days. No care whatever is taken to prevent the flow of latex over the wound. In fact in the opinion of some workers the latex actually seems to promote the graft. So far as is known, *Cryptostegia* is the only rubber-bearing latex plant which can be grafted easily. Among the grafts successfully being made are: patch and insert budding; insert (or side) and cleft grafting on to stems; and insert (or side) grafting on to roots. It should be noted that failure attended efforts to obtain the practical rooting of cuttings.

Research into the possibilities of seed breeding has been started and evidence already collected indicates that the plant produces genetically pure lines very readily. Among this evidence is the fact that in Haiti and elsewhere, in Mexico and in Texas, aggregations of plants descended from single parents display marked uniformity. It is hoped to develop pure lines for certain desirable characteristics such as high latex yield, ease of latex flow, high rubber content of latex, high T-whip production, large T-whip diameter, and disease resistance. It is also hoped to obtain races showing inter-strain hybrid vigour.

Coagulation and Sheeting

As stated, the major problem of converting latex into commercial crude rubber has already been solved. In the pilot-plant at Gonaives the technique is as follows: latex, purchased from farmers, arrives at the factory in every sort of receptacle, much of it having been gathered 24 hours and even longer before delivery. Bulked in buckets, it is then measured into a 2½ gallon shallow pan made by cutting a five-gallon gasoline can along its long axis. One litre of latex is poured into the pan, and six volumes, a practical optimum, of water added. Then the resultant mixture is stirred for a few moments, and froth and floating impurities are removed with a wooden skimmer. The mixture is left undisturbed 45 minutes, when it is found that the latex has formed a soft, "fish-belly white" coagulum about three inches thick. This soft cake is gently separated from the sides of the pan with a wooden knife and without being removed is manipulated momentarily to remove the larger entrapments of fluid and air. This reduces its thickness by about half. The coagulum is then lifted and fed into the first of a series of five standard hand-operated rolls, the last of which is a marking roll. The rolls are kept wet with water sprays.

From the marking roll the sheet emerges, glistening white and firm, yet soft in texture. The coagulum, while it is forming, is slightly photo-sensitive; grayish streaks appear on its surface unless it is shielded from the light while it remains in the pan. Once lifted from the pan, it seems to lose this light sensitivity. The water remaining is turbid, turning straw colour upon exposure to light. It is believed that a large part of the latex resin remains with the serum in solution with the water.

The sheets have been both smoked and air-dried, and so far it would seem that no difference exists in the final product or its keeping characteristics regardless of treatment. It is likely that air drying will be adopted as a final procedure. Gradually, after being dried, the sheets take on the amber color and translucent appearance of light-smoked sheets.

Properties of the Rubber and Latex

The qualitative examination of the SHADA sheets by the Bureau of Standards show that the rubber is substantially of the same quality as that produced by alcohol coagulation; the water coagulated samples in fact score a little better. Every determination of *Cryptostegia* rubber has shown it of high quality, comparing well with first-quality *Hevea*, and the SHADA samples are no exception.

The following analysis of a blend of alcohol and water coagulated sheets is taken from an unpublished report on *Cryptostegia* by Ernst A. Hauser.*

	Per cent.
Acetone extract	8.83
Acid in acetone extract (as oleic) ..	0.42
Ash	0.81
Nitrogen	0.71
Moisture	0.33

Primed ribbed sheet give the following:—

	Per cent.
Acetone extract	3.66
Acid (as oleic)	1.57

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A SIMPLE METHOD OF PROTECTING CEREALS AND OTHER STORED FOODSTUFFS AGAINST INSECT PESTS *

BY

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Introduction

Until recently relatively little attention has been paid in Great Britain to insect pests of stored foodstuffs. Recent scientific surveys have proved that, although heavy infestation is exceptional, some degree of infestation is widespread, and is often regarded as "normal". No estimate of the extent of damage caused by insects in Great Britain has yet been made, but the aggregate effect is certainly very large. In Germany, one authority estimated that 1 per cent. of the total grain harvest is actually destroyed annually by grain weevils, while a far larger proportion is spoiled in quality. In the United States of America according to one estimate quoted by the Senior Entomologist of the United States Department of Agriculture, insect pests of stored grain and cereal products cause damage to the extent of $300,000,000 a year. These losses were not regarded very seriously in peace-time, but in war they are certainly important, not only on account of the shipping space involved, but also because grain has often to be stored under unfavourable conditions which render it particularly liable to infestation. It is well known that for this reason very large quantities of grain were destroyed by weevils in Australia in the last war, and the risk of a like disaster exists now and may well become great in the post-war distribution of food in Europe.

Inert Dusts: A Simple Method of Protection

It has long been known that a simple method of protecting foodstuffs such as wheat from insects is by the use of certain inert, non-poisonous *dusts* which, when mixed with the stored product, not only destroy any insects already present, but also provide a standing safeguard against re-infestation. With suitable dusts, the quantity needed is relatively small, and trials have shown that it is later completely removed by the normal cleaning processes prior to milling. In any case, the dust may be so chosen as to be quite innocuous and the baking quality and germinating power of the grain are unaffected by it. Adequate authority for these statements may be found in the following extract from a Colonial Office Memorandum published in 1940. "In recent years the use of dusts for the protection particularly of grain and cereal products has become more and more general . . . From the practical man's point of view, the main point is that these dusts are said to be surprisingly effective, and, further, the variety of mineral dusts which are effective is considerable. Of the natural mineral dusts, the best known and probably the most effective is naturally occurring rock phosphate widely known in Egypt under the name of "Katelsousse" . . . Other effective dusts consist of pure silica, and one of these, known under the proprietary name of 'Naaki,' has been widely used in Germany and elsewhere . . ." The Memorandum summarizes the matter with the words:—"Of all the methods of protecting grain and seeds in particular against attack, it would seem that the use of dusts is much the more promising." More recently, the Australian Council for Scientific and Industrial Research (15th *Annual Report*, 1940-1941) reported gratifying results with several local non-siliceous mineral dusts, and further experiments with "Naaki" have been made by the United States Department of Agriculture. Several commercial products are on the market in this country.

Attempts to Produce a More Effective Inert Dust Insecticide

Since the outbreak of war, a study of the effects of inert dusts on insects has been carried out in the Department of Inorganic and Physical Chemistry of the Imperial College of Science and Technology† with the object of discovering the mode of action of such dusts and hence developing a practical insecticidal dust of the highest possible effectiveness.

It is now known that the action of these dusts does not depend on any chemical reactivity, but is determined by their physical properties, particularly the particle size of the dust and the intrinsic hardness of the material. Their "toxicity" to insects is due chiefly to the fact that they promote loss of moisture by evaporation through the insect's cuticle, a process which, sooner or later, results in death by desiccation since insects living on dry food cannot make good the water deficiency the dust creates. Any hard mineral when ground sufficiently finely is moderately effective in killing, for example, the common grain weevil (*Calandra granaria*), and treatment of grain with 1 per cent. by weight of such a product would provide good protection. Unfortunately there are certain limitations on other grounds to the use of mineral dusts. The chief is that the majority of commonly-occurring hard minerals contain large amounts of silica, and as fine powder constitute a potential cause of silicosis in operatives handling the dusted grain. For this reason all forms of silica, and probably most silicates, must be considered unsuitable for use as dust insecticides. A comprehensive survey was therefore made of hard minerals and industrial materials available in Great Britain. It was found that several are

* Reproduced from *Chemistry and Industry*, Vol. 62, No. 4, 1943.

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moderately suitable, but none ideal. Minerals of intermediate hardness, such as dolomite, would be quite safe, but their effectiveness is markedly inferior to that of harder substances. One very promising material discovered was coal-ash clinker, which is available cheaply in large quantities from power plants. Clinker is chiefly a complex silicate of iron and aluminium, and it appears probable that since the silica is firmly bound, it is less liable than other siliceous minerals to present a silicosis hazard. The Australian Council for Scientific and Industrial Research has reported that magnesite, limonite, calcined distomaceous earth, ferruginous bauxite, and dolomite are effective materials, magnesite being the best of this group: but it must here be remarked that the standard of effectiveness considered satisfactory by the Council lies below that which we regard as good. Two objections have been raised to the proposed use of mineral dusts for the treatment of stored grain. First, dusts are alleged to spoil the appearance and free-running properties of the grain. Secondly, the cloud of dust which is raised in the mill when dusted grain is moved is said to be excessive. While in some cases these disadvantages are clearly of less importance than the saving of the grain itself, they are probably serious enough to discourage the universal use of dusts. There must nevertheless still be many occasions, especially in war-time when dusts could be profitably used.

A New Type of Inert Dust

The above account summarizes the information hitherto available regarding practical inert dust insecticides. It is fairly certain that a product of maximum effectiveness is obtained from the hardest possible material by grinding it in a suitable manner to a certain optimum particle size. A few months ago it seemed probable that no further improvements in mineral dusts could be expected and that the effectiveness attained by the hardest dusts, such as carborundum or diamond, ground to a size or 2-5 microns, could not be exceeded. Quite recently the position has been completely changed by our discovery of a new dust having an effectiveness of an altogether higher order. It is a fine white powder produced by a chemical process, is chemically inert, insoluble in water, non-poisonous, and free from any danger of silicosis. It is about *ten times as effective* in destroying grain weevils as the best mineral dusts previously known; so that a dosage of *only* 0.1 per cent. is as effective as 1 per cent. of other dusts. For example, under the conditions used in the laboratory tests 1 per cent. of the best hard mineral dust added to wheat would kill in a week about 30-40 per cent. of any grain weevils present; an "effective" dust of the kind used by the Australians would kill 10-20 per cent. under the same conditions. 1/10 per cent. of the best mineral dust would kill no more than about 5 per cent. of weevils in the same time, but 1/10 per cent. of the new dust under the same conditions would give a kill of 40-50 per cent. Judged in this way the new dust may be regarded as more than ten times as effective as any already known. One remarkable property of the new dust is its extraordinary "lightness" which, combined with the fact that it does not adhere to grain to any visible extent (as other dusts do), enables a small amount o dust to be distributed very easily in a large bulk of grain. Even more remarkable is the fact that infinitesimal amounts of dust suffice to kill the weevils. In contrast with the behaviour of all other dusts, it is only necessary for grain weevils to come into contact with this dust *once*, since the almost invisible film of dust which adheres to them has substantially the same effect as constant contact with excess dust. This means that complete mixing of the dust with the grain is not important, for insects which enter a clean zone of wheat by migrating through a dusty zone are unlikely to survive. Equally important from the practical standpoint is that the reduction of the dust dosage from 1 per cent. to 0.1 per cent. should remove the difficulties hitherto felt by the millers in the use of dusts. Grain dusted with the new product is scarcely distinguishable in appearance from untreated grain.

This new dust is not only by far the most effective known for combating the common grain weevil (which is probably the most serious pest of stored products), but it is also found to kill other species—for example, the Rice Weevil (*Calandra oryzae*), both larvae and adults of the two Flour Beetles (*Tribolium confusum* and *T. castaneum*), the Spider Beetle (*Ptinus tectus*), and larvae of the Mediterranean Flour Moth (*Ephestia kuhniella*) and of the Meal Worm (*Tenebrio molitor*). Experiments in other laboratories have further shown that ordinary inert dusts are effective against larvae of the Cocoa Moths (*Ephestia elutella* and *E. cautella*), and the closely related *Plodia interpunctella*, the Bean Weevil (*Acanthoscelides obtectus*), and mites. It may therefore be anticipated that the new dust should serve to protect most stored foodstuffs effectively against any of the common insect pests. Dusts would naturally be used on the original grain, pulses, nuts, cheese, dried fruit, &c., and not on pulverized products such as flour or bran. If necessary, the grain would first be screened to remove organic dust. Though heavy infestation should be dealt with by fumigation, the *prevention* of infestation is the ideal use for mineral dusts which should be added to the foodstuff at the earliest possible stage. The new dust is still in the experimental stage but it has already been fairly extensively tested at Imperial College with the results outlined above. At present it is being made on the laboratory scale and is costly to produce. There is, however, nothing inherently difficult or expensive in the method of preparation, and there is every reason to believe that eventually it could be available on a large scale at a reasonable price.

LOCUST INVASIONS AND THEIR CONTROL*

BY

A. D. Imms

Locusts belong to the family Acrididae which comprises the common or short-horned grasshoppers. Several thousand species of Acrididae are known, but fortunately only a small number comes into the category of locusts. A locust may be defined as a species of short-horned grasshopper, which, at times, becomes predominantly gregarious and migrates considerable distances in great swarms. The depredations of these insects have menaced the food supply of man ever since he adopted agriculture. References to locusts and their activities occur in the writings of Pliny, and in many Chinese, Egyptian, and Greek texts, besides the familiar Biblical allusions. The earliest discovered record of these insects is stated to be a representation of a locust on the wall of an Egyptian tomb, dated about 2400 B.C.

The life-cycle of a locust is as follows. The eggs are deposited by the female below the soil in 'pods' or packets. In countries with a cold winter the eggs remain dormant throughout this season until the spring, when the young insects or "hoppers" emerge. In the tropics they hatch within a few weeks of being laid, provided there is sufficient moisture. The difference between grasshoppers and locust first becomes evident in the hopper stage: with the former the individuals are solitary or, in other words, each lives independently of the others, whereas in the latter they congregate in dense bands. Further development consists in rapid growth, together with periodic moulting of the skin, which occur four to six times before the adult insect appears. The whole cycle lasts for about a year in temperate climates, but in the tropics there may be two or three generations in a year. Locust hoppers betray mass movements in bands that may be spread over several square miles. Eating all in front of them, these hordes of individuals move relentlessly forward irrespective of obstacles. An impelling force urges this movement; it is not hunger, since they often leave a fertile zone to enter an arid one. Recent research has proved that these movements are dependent upon temperature and occur only when it is sufficiently high, while excessive heat, like too low a temperature, checks them. The winged adults, like the hoppers from which they have been transformed, also betray mass movements, since they take to the wing in vast swarms. These similarly are impelled into such activity by causes other than mere lack of food.

Two main phenomena have long stood in the way of a solution of the locust problem. First, the more or less irregular periodicity of the outbreaks: they are not annual events but recur in cycles of several years. Anti-locust measures are speedily organized and their application may alleviate pressing needs, but they are usually applied too late, besides leaving the menace of subsequent swarms uncatered for. The second is that swarms may arise in one country and cause depredation in numerous other lands along their paths. Yet, however effective the measures taken in these individual countries may be, they have no bearing on the general situation, viz. the source of origin of the swarms. To quote one example, swarms of the Desert Locust commonly arise in India during the summer monsoon rains, and migrate to Persia and Arabia, where their progeny give rise to further swarms that may pass on to Soviet Asia, Palestine, Iraq, Egypt, and East Africa. Lack of fundamental knowledge, and of a guiding policy for anti-locust measures founded upon it, have, therefore, from time immemorial frustrated human efforts to cope with the menace.

In 1921 B. P. Uvarov, of the Imperial Bureau of Entomology in London, advanced what has subsequently become known as the phase theory of locusts. Subsequent observations made in South Africa in 1932, both in the laboratory and in the field, by J. C. Faure, and by other workers elsewhere, have so fully corroborated the main contentions of Uvarov that his phase theory is regarded today as an established biological phenomenon. The starting-point of the theory is that a locust can exist in three biological phases, *viz.* a solitary one (*phasis solitaria*), a gregarious or migratory one (*phasis gregaria*), and a transitional one (*phasis transiens*). Taking the African Migratory Locust (*Locusta migratoria migratorioides*), as an example, the *phasis gregaria* in its hopper stages is constantly coloured black and deep orange-yellow. The adults have a short, constricted pronotum, and the ratio of the length of the fore wing to that of the hind femur is equal to or greater than 2. In the *phasis solitaria* the hoppers are variably coloured and tend to simulate the hue of their immediate back-ground. The adults have a longer and broader pronotum with a dorsal keel and the wing/femur ratio is always less than 2. The *phasis transiens* is not represented by any definite form, but is intermediate in its characters between the other two phases.

By varying the conditions, locusts can be reared experimentally from the eggs in such a way as to develop into whichever of the phases is desired. If a large batch of hoppers be reared under crowded conditions in a single cage they become extremely active and develop into a close approximation to the gregarious phase. Under

* Re from *Endeavour*, Vol. II, No. 6, 1943.

less crowded conditions they display the *phasis transiens*, while individuals reared in separate containers grow into the solitary phase, the hoppers taking on the general colour of their surroundings. The great activity and consequent high metabolism of the gregarious individuals lead to the differences separating them from those in the solitary phase.

The periodicity of locust outbreaks is now known to be connected with the transformation of these insects from the harmless solitary phase into the destructive migratory one. This transformation occurs in certain localised areas, known as outbreak areas, which have special conditions of climate and vegetation for each locust species. It is here that the great swarms develop. In the African Migratory Locust, swarms that arose about 1928, in a restricted area of the Middle Niger in the French Sudan, were the cause of an invasion involving a great part of Africa. Some of the outbreak areas of the Desert Locust (*Schistocerca gregaria*) have been located in lands bordering the Red Sea, while swarms of the Moroccan Locust (*Docisotaurus maroccanus*) develop on stony hillsides where vegetation is rather scanty. The extensive movements of locust swarms make it futile for each country to attempt its own isolated control measures; failure to repress these plagues has actually been due to isolationist policy. In 1928 a severe outbreak of the Desert Locust was the moving factor in causing the British Government to take steps towards coping with the problem by setting up a special research organization. This purely British venture led to the first International Locust Conference being held in Rome in 1930 (the fifth Conference was held in Brussels in 1938). This body requested the British organization to act as an international centre for collecting information and formulating research procedure. Today a special Anti-locust Research Centre in London operates under the supervision of Sir Guy Marshall, F.R.S., with Dr. B. P. Uvarov as its technical organizer. Concerted investigations by parties of British, Belgian, French, South African, Egyptian, and Indian experts have collected a vast number of field data. Under great difficulties, the outbreak centres of locusts are being located and kept under observation - often in remote and inhospitable territories. By this means any tendency towards swarming can be noted and, at the same time, lands likely to be affected can be forewarned and so be in a position to apply timely measures. Ultimately, developing swarms may be destroyed in these centres, or the ecological conditions prevailing there may be altered by cultivation or other means so that they no longer give rise to locust swarms.

BUILDING BREEDS FOR THE TROPICS *

BY

A. O. RHOAD

AGRICULTURAL leaders throughout the American tropics generally recognize that new breeds of beef and more especially dairy cattle adapted to the rigours of a tropical environment must be evolved. Recent research in Brazil, the United States, and South Africa has clearly shown that ability to stand tropical climatic conditions is as much an inherent characteristic of breeds as capacity to produce milk or beef. Experience and experiment have also shown that in general the highly specialized breeds of European origin have low tolerance for heat and do not thrive in warm climates, while breeds of Indian origin and some of the native cattle of Central and South America show high tolerance for heat and are, therefore, constitutionally suited to develop in a tropical environment.

To combine the capacity for high production of European cattle with the high resistant qualities of the zebu or native cattle in order to develop new superior types is one of the major breeding problems confronting the improver of livestock in the tropics.

Contributions of the Santa Gertrudis Breed

In the solution of this problem the Santa Gertrudis beef cattle have made two very significant contributions which are of interest to the breeder of cattle in the tropics. They are, first, that starting with good foundation stock, new and improved breeds of cattle can be evolved through judicious cross-breeding, skilful selection and intelligent mating; and second, that the beef production of tropical cattle can be improved through grading-up to a breed of predominantly European blood, without materially reducing the heat tolerance or adaptability of the progeny.

Crossbreeding the heat tolerant zebu or native cattle with the highly specialized European breeds is one of the methods through which new and improved breeds adapted to the tropical environment may be evolved. It is, however, the most precarious method at the disposal of the breeder. It is harzadous, for it necessitates the mating of crossbred sires with crossbred dams; if not systematically done, such mating will more often bring about the creation of nondescript herds of low market value than the establishment of new improved types. The possibility of the establishment of new and improved breeds through careful crossbreeding of European and Indian cattle is one of the important contributions of the Santa Gertrudis to livestock improvement in the tropics.

The establishment of new breeds through crossbreeding is a long process, which usually requires many years of continuous effort. It has often

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been debated as to whether new breeds of our larger farm animals can be evolved within the lifetime of an individual breeder. The Santa Gertrudis breed proves the possibility, for 22 years after the crossing in 1918 of zebu bulls on purebred Shorthorn cows, the descendants were recognized as a distinct breed.

A quarter of a century is about as short a period as can reasonably be expected in which to develop new breeds of cattle. Considering that some of our modern breeds have taken centuries to develop their present well-balanced form and high productive efficiency, this is a very short time. Science and the practical breeder have been largely responsible for the more speedy arrival at the goal set. With the aid of our present knowledge of the science of animal genetics, the livestock breeder can follow proved procedures and avoid some of the costly pitfalls in his breeding operations.

The development of superior new breeds of large farm animals through cross-breeding is not a recommended task for the breeder with a small herd, limited time, and capital; it takes considerable equipment, experience, and technical knowledge to achieve success. It is, however, a proper field of endeavour for government experiment stations or large ranches where material is available and continuity of effort is assured.

For these reasons not many breeders and only some agricultural experiment stations will undertake the task of developing, for the tropics, superior new breeds through crossbreeding. On the other hand, most breeders are concerned with improving the productive capacity of their herds for immediate commercial purposes. The time-honoured system of attaining this end has been the practical method of grading-up the herds to an improved type by use of pure bred sires. This method has been very successful in many parts of the world. The generally high quality of farm animals in the United States is the result of a long grading-up of common herds by the use of purebred sires. It is the recommended method where the purebred sire is of a breed adapted to the environment in which it is placed.

In the tropics the method has not proved successful with cattle, when purebred sires of European origin have been used. Grading-up to the improved type of zebu or native cattle, on the other hand, is successful and is being done on a large scale in many parts of the American tropics. The failure, in the tropics, of grading-up to the European type is attributed to several causes. European breeds generally are not adapted to a tropical climate because of their low heat tolerance. When bulls of these breeds are continuously used in grading-up tropical types of cattle, they greatly reduce the heat tolerance of the progeny. As a result the progeny decrease in size, vigour, and productiveness.

To overcome this degenerating effect of grading-up to the low heat tolerant breeds, it is the practice in some regions to "refresh" the herds by returning occasionally to the use of zebu or native type bulls. This practice, technically known as backcrossing, has been employed successfully with beef cattle along the Gulf Coast of the United States and in Minas Gerais, Brazil, and in Trinidad with dairy cattle. After the heat tolerance of the herds has been re-established through back crossing, the grading-up method may continue through the use of purebred sires of the European breed originally selected for grading-up.

There are other factors that have caused the failure of grading-up to European breeds in the tropics. Most important of these has been the high mortality of the purebred sires, especially when placed under range conditions. Another is the low fertility of the European type of bulls in the tropics. Recent research at Purdue University and the Bureau of Animal Industry has shown that continuously high atmospheric temperatures materially lower the fertility of the males of low heat tolerant breeds of cattle.

Before a continuous grading-up programme can be effective in the tropics, it is necessary to have breeds of high productive efficiency possessing high tolerance for heat. When continuously crossed on low producing cattle of the tropics, these breeds will progressively improve the productive efficiency of the offspring without materially lowering their heat tolerance.

Developed by crossbreeding the zebu with the Short-horn, the Santa Gertrudis is the first American breed of predominantly European blood which possesses high productive efficiency and high tolerance for heat. Considerable numbers of Santa Gertrudis bulls are being used in several Central and South American countries in grading up native type cattle. The results are being watched with interest.

In the future other new improved beef breeds carrying a high proportion of the blood of some specialized European breed with sufficient zebu or native blood to assure adaptability to warm climates, may be evolved and used in grading-up programmes. For the present only the Santa Gertrudis is available.

An improved tropical dairy breed of European-zebu or European-native blood is non-existent at the present for use in improving dairy cattle in the tropics through the grading-up process. The creation of such a breed awaits the skill of some master breeder.

VEGETATIVE PROPAGATION OF MANGOES

According to an article published in *Curr. Sc.*, **10**, p. 297, the application of 3 per cent. indoleacetic acid to the ringed portion of marcots when wrapping and to a girdled section at the base of a cutting 24 hours before severance from the mother plant proved a very successful method of rooting when young mangoes 2 to 3 years old were the parent plants. Cuttings from untreated controls or from treated mature trees did not root. One per cent. and 3 per cent. naphthaleneacetic acid was ineffective.

FORMATION OF WATER-STABLE STRUCTURE IN PUDDLED SOILS *

Effect of Organic Matter and Microbiological Activity on Development of Water-stable Aggregates in Soil

Studies of the beneficial effect of organic matter on soil structure have led naturally to investigations of the microbiological processes responsible for the chemical and physical changes in organic materials upon their return to the soil. The exact nature of the changes and their influence on structure have not been worked out. It is generally thought (1), however, that the effects of organic matter on structure may be due to the binding action of the decomposition products of plant residues, to mechanical binding by microbiological growth structures such as fungal mycelia or masses of bacteria cells, and to the cementing action of secretory products of micro-organisms such as mucus, slime, or gum.

Chemical changes resulting from microbial activity doubtless affect the nature of the materials that hold the discrete particles in clumps. Myers (2) assumed that colloidal organic matter and inorganic colloids united chemically and thought that the stability of aggregates bound by organic colloidal material was due to the irreversibility of such colloids following dehydration. Sideri (3) believed aggregates resulted from the establishment of a firm bond between clay and quartz sand, the nature of the aggregates depending on the colloid part (4). Furthermore, he (3) claimed that a clay-humus bond developed as a result of mutual orientation based on similar crystalline periods. Where an excess (5) of humus occurred in a sand-clay-humus mixture, the mass, on drying or freezing, would separate out into two parts, one containing an anisotropic combination of sand, clay, and humus, and the other, organic matter. This latter material, because it had a higher surface tension than the anisotropic centre, would separate from the mixture after the clay was "saturated" with humus and distribute itself at the periphery of the anisotropic central mass, producing the typically spherical shapes of granular aggregates.

It is difficult to separate the granulating influence of organic compounds in the soil from the influence of calcium, hydrogen, iron hydroxide, and other materials known to be associated with aggregation. In some cases the granulation may possibly result from some combination of such materials. Martin and Waksman (6) noted that the effect of lime on aggregation seemed to be associated with its effect upon the action of the organic binding material, an observation in line with the ideas of Kubiena (7) and of Bradfield and Jamison (8), who suggested that soil structure formation depended more on concentration processes than on the flocculating effect of calcium. The rôle of lime on granulation may lie in its effect in creating a medium favourable to the production of sticky materials in the decomposition of organic matter. Shrikhande (9) found a neutral reaction essential to the production of stickiness in manure heaps.

Soil treated with organic matter and incubated at favourable moisture and temperature conditions will be bound into rather stable masses by intrictae, interlacing networks of fungal mycelia. This phenomenon can be readily observed and has been described by Waksman and Martin (10). There is some speculation that soils may be bound into aggregates by masses of bacterial cells.

It was noted that certain organic materials such as celluloses and oat straw would yield sticky mucilages (11), (12), (9), (13). This suggested the possibility of such materials acting as binding substances for soil aggregates (14), a possibility which was successfully explored by Kanivetz and Korneeva (12), Martin and Waksman (6), Peele (1), and Peele and Beale (14).

Peele (1) found that pure mucus produced by bacteria could effectively bind soil into water-stable aggregates, provided the soil and mucus were kneaded together into granules and air-dried. The binding action was attributed to the natural cohesion of the mucus for soil and to the irreversibility of the mucus on dehydration. Additions of sucrose to Cecil sandy loam and inoculation with micro-organisms resulted in an increased number of large water-stable aggregates upon incubation. When added under aseptic conditions, the fungi were more effective than bacteria.

The natural assumption has been that anything which increased the number of large water-stable aggregates would increase infiltration and decrease runoff. Peele and Beale (14) tested this theory in field plots where they checked the actual effect on erosion of the aggregation resulting from additions of organic matter and microbiological cultures to soil. Sucrose plus inoculation with *Penicillium oxalicum* produced both an increase in aggregation and a decrease in runoff and erosion.

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* Abstracted from an article by J. B. Peterson in *Soil Science*, 1943, Vol. 55, No. 4, p. 289.

CHEMICAL NOTES

(Compiled by the College Department of Chemistry and Soil Science)

The Vitamin Content of Vegetables

Determinations of the vitamin contents of a large number of different varieties of vegetables grown throughout the year in the R. H. S. gardens yielded the following data: *Vitamin A*. In carrots this vitamin increases with the age of the root but becomes less readily available. Cauliflower leaves possess a high nutritive value. The green parts of salad onions highest in nutritive value are those usually thought to be the least edible. *Vitamin B1*. Vegetables, though not containing high concentrations, can be considered as active contributors to the diet. *Vitamin C*. In war time, vegetables provide almost the sole supply of vitamin C, the green leafy vegetables containing very high concentrations especially when young. Between early and late growing varieties there is a striking difference (up to 5 times as great) in favour of the former so that in assessing the nutritive value of a diet, of cabbage for instance, allowance must be made for the time of the year. Vegetables richest in *Vitamin A* appeared to be spinach, cauliflower leaves, parsley, carrots; in B1, Jerusalem artichokes, peas, parsley, garlic, spinach; and in *C*, spring cabbage, sprouts, broccoli, parsley, kale and spinach.—(*Horticultural Abstracts*, XIII, No. 2.)

* * *

More Rubber from Castilla

The implications are discussed in *Agric. Amer.* 3, 7-9 of an accidental discovery that rubber latex can be coagulated inside the bark of *Castilloa* spp. by the application of sufficient heat to destroy the oxidizing enzyme that prevents coagulation and eventually reduces the rubber to a soft adhesive paste. When the enzyme has been destroyed it is suggested the felled trees should be allowed a short period for decay after which the inner rubber-bearing layers of the bark may be separated. At first the many abandoned *Castilloa* plantations in Mexico and Central America could be treated but eventually a stabilized industry would follow forestry methods in growing the trees and lumbering the trunks and branches to a mill for extraction of the rubber, with the bark fibre and wood as by-products. Self-renewing *Castilloa* forests could readily be established. The method of tapping normally used in South America is to fell the tree and then ring the trunk and larger branches. Although 20-50 lb. is extracted from the larger trees the latex flows only to the extent of relieving the bark pressure and several times as much rubber must be left in the bark. *Castilloa* cannot be tapped at frequent intervals as with *Hevea* because the latex tubes do not form a continuous network so that the bark pressure adjacent to the wound is not restored.—(*Horticultural Abstracts*, Vol. XIII, No. 2.)

Hoeing

A summary of the effects of cultivations on farm crops as deduced from experiments performed at Rothamsted and elsewhere appears in the *J. Roy. Hort. Soc.*, 67, 1942 (323-328). Special attention is given to effects on movement of soil moisture and on weed competition. The capillary theory of movement of moisture has been shown to be quite inapplicable to soil. Hoeing merely produces mechanically what will happen naturally, since soils are "self-mulching." Hoeing is not a direct moisture-conserving operation. The value of hoeing apart from its important effect of weed destruction is that it will counteract the tendency of heavy soils to form a hard dry crust and to form cracks from which moisture in the depth is easily lost by evaporation.—(*Soils and Fertilizers*, VI, No. 1, 1943.)

* * *

Quick Method of Making Humus

A new system of composting has been devised in New Zealand (*N.Z. Jr. of Agric.*, 64, 125), whereby complete breakdown of material is achieved in a few weeks. It differs from ordinary composting only in that air vents are introduced into the base of the heap. The necessary plant is an above-ground receptacle of cement and boulders, divided midway by a partition. At the bottom of each container a 12 in. square is dug and covered with heavy wire netting, while leading to the outside from each square is a 9 in. pipe. The indraught of air through these pipes appears to stimulate the heating process, though larger pipes tend to slow down combustion. Material placed in one container is turned into the other after three weeks and is ready for use a month or six weeks later.

* * *

A Method of Storing Sweet Potatoes

According to an atricle in the *E. Afr. Agric. J.* 8: 73, sweet potatoes can be stored for two years or more if treated as follows. The tubers are dug and wilted for two or three days, then placed in cold water, brought to the boil and kept boiling for an hour. They are then removed, cooled and either sliced lengthways into three or four pieces, or squeezed out as flat as possible with the fingers, and afterwards dried brick hard in the sun. They are now ready for storing, no special storage vessels being required. When required for use the dried roots are washed and boiled in the ordinary way. The result is said to be even more palatable than boiled fresh roots. The method is used by the natives of Sukumaland in the Lake Province of Tanganyika. It is possible that under more humid conditions than are usual in that region the method might be less satisfactory.